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ABSTRACT

The oolitic ironstone level occurring at the Callovian-Oxfordian boundary across wide areas in the central Iberian Range (Eastern Spain) is interpreted here as formed on an extended, very shallow to temporarily emerged, uniform carbonate platform. Main evidence to support this interpretation comes from both sedimentological analysis of facies and taphonomic analysis of the ammonites. The sedimentological analysis gives support to the idea of iron oolites being formed on, or in the surroundings of, emerged areas. On the other hand, the taphonomic analysis shows that some inner moulds of ammonites from this level display evidence of taphonomic reworking, such as the presence of ellipsoidal abrasion facets on the final part of the last preserved whorl, or annular abrasion furrows carved on the external region. These features would have developed by the action of directional currents under extremely shallow conditions. Bathymetric implications are relevant for the interpretation of the sea level fluctuations at this stratigraphic interval: A relative lowstand of sea level is proposed for the Upper Callovian-Lower Oxfordian interval in the studied area.

KEY-WORDS: FACIES ANALYSIS, TAPHONOMIC ANALYSIS, EUSTATIC CHANGES, CALLOVIAN-OXFORDIAN BOUNDARY, IBERIAN RANGE.

RÉSUMÉ

Le niveau d'oolites ferrugineuses situé à la limite Jurassique moyen-supérieur, rencontré sur une grande partie de la Chaîne Ibérique (Est de l'Espagne), est interprété comme ayant été formé sur une plate-forme carbonatée uniforme, très étendue et peu profonde, voire localement émergée. Cette interprétation est basée sur l'étude sédimentologique des faciès et l'analyse taphonomique des associations d'ammonites. L'étude sédimentologique étaye bien l'hypothèse de la formation du niveau oolitique sur, ou proches, des aires émergées. D'autre part, l'analyse taphonomique a montré la présence dans ce niveau de moules internes d'ammonites qui présentent notamment des facettes ellipsoïdales d'usure recoupant le dernier tiers de spire ou des sillons annulaires d'usure, interprétés comme preuves de remaniement des moules internes, et probablement dûs à l'action des courants directionnels en milieux extrêmement peu profonds. Ces implications sur la profondeur des eaux au-dessus de la plate-forme et les variations de la bathymétrie sont d'importance primordiale pour l'interprétation des fluctuations du niveau marin pendant cet intervalle stratigraphique. Une phase de bas niveau relatif est proposée pour l'intervalle Callovien supérieur-Oxfordien inférieur dans la région étudiée.

MOTS-CLÉS : ANALYSE DE FACIÈS, ANALYSE TAPHONOMIQUE, CHANGEMENTS EUSTATIQUES, LIMITE CALLOVIEN-OXFORDIEN, CHAÎNES IBÉRIQUES.

INTRODUCTION

A thin oolitic ironstone level, from few centimeters up to one meter thick, bearing hemipelagic and benthic marine fossils (ammonites, belemnites, brachiopods, gastropods, echinoids, sponges) crops out throughout western and southern Europe at the Middle-Upper Jurassic boundary. The

origin and bathymetric depositional conditions of this level has been the subject of discussion for decades. Some authors have interpreted it as generated in a relatively deep marine environment (Geyer *et al.* 1974, Iberian Range ; Gygi 1981, 1986 ; Swiss Jura basin ; Vail *et al.* 1987, Paris basin). An opposite interpretation has been proposed by other authors in the Iberian Range, who

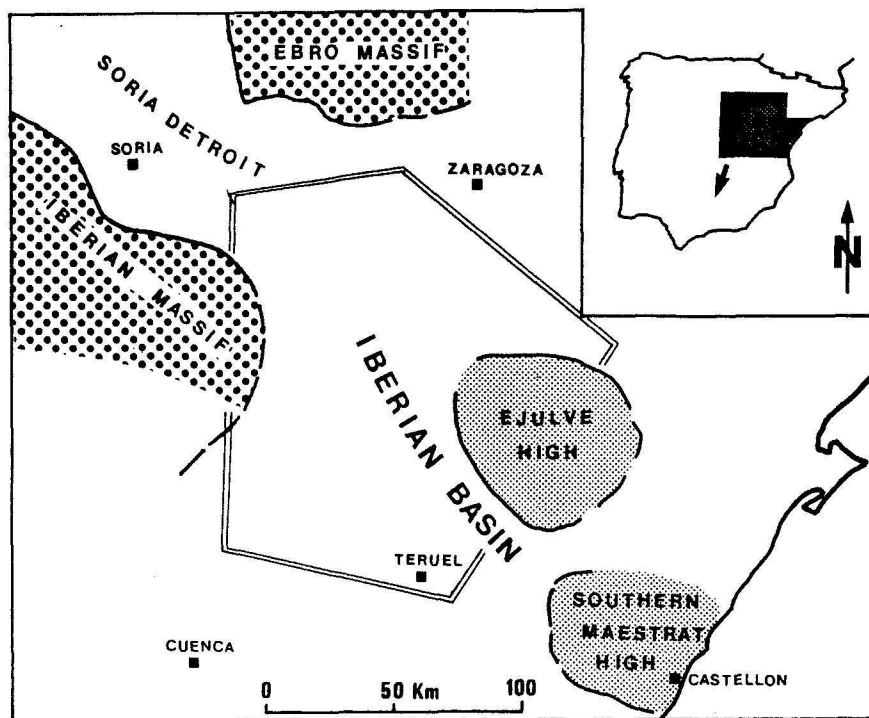


Figure 1 - Paleogeographic reconstruction of NE Iberia at the onset of the Upper Jurassic (compiled from Bulard 1972 ; Gómez 1979 ; Aurell & Meléndez 1993). *Reconstitution paléogéographique de la partie NE de l'Ibérie au début du Jurassique supérieur (d'après Bulard 1972 ; Gómez 1979 ; Aurell & Meléndez 1993).*

regarded this level as formed under shallow bathymetric conditions (Gómez 1978 ; Benke 1981 ; Mensink & Mertmann 1984 ; Wilde 1988, 1990). More recently, this same interpretation has been put forward by some of the present authors, considering this level as deposited under extremely shallow to emerged conditions (Fernández-López 1985, p. 121 ; Meléndez *et al.* 1990 ; Aurell 1990, 1991 ; Aurell & Meléndez 1993).

In this paper, after a general review of previous ideas, we report the arguments to regard this bed as formed under very shallow marine and locally emerged conditions, interrupted by ephemeral episodes of marine flooding. These are based on 1, extensive sedimentological facies analysis across the basin ; 2, the stratigraphical distribution of ammonite assemblages in this level, and 3: the taphonomic analysis of the ammonites recorded within this level throughout the Iberian Basin.

FACIES ANALYSIS

The oolitic ironstone level, located at the Middle-Upper Jurassic boundary, is a 0.1 to 0.9 m thick limestone bed widely spread throughout the central and eastern part of the Iberian Range. The studied outcrops are placed in the northeastern part of the so-called Iberian Basin, which developed in eastern Iberia, eastwards from the emer-

ged areas of the Iberian and the Ebro massif (Fig. 1).

PALAEOGEOGRAPHICAL REMARKS

Successive shallow and low-angle carbonate ramps developed during the Jurassic in the Iberian Basin. Between the Middle Callovian and Middle Oxfordian this ramp was probably an extended, uniform and flat surface, as it can be inferred by the remarkable homogeneity and extension of facies across wide areas of the Iberian Basin, such as the oolitic ironstone level and the sponge and ammonite limestone facies at the Middle Oxfordian (Aurell & Meléndez 1993). Some relief on this ramp appears, however, in several areas which remained as sedimentary highs during the deposition of Upper Jurassic sediments.

Tectonic activity of some basement accidents during the Middle Jurassic resulted in the breakdown of the Lower Jurassic ramp and its division in furrows and sedimentary highs (Gómez 1979 ; Canerot 1985 ; Fernández-López & Gómez 1990). The resultant relief was generally filled up and homogenized at the end of the Callovian (Lardiés 1990). A series of sedimentary highs remained at the onset of the Upper Jurassic, such as the so-called Ejulve High (Bulard 1972 ; Gómez 1979 ; Aurell & Meléndez 1993). The Ejul-

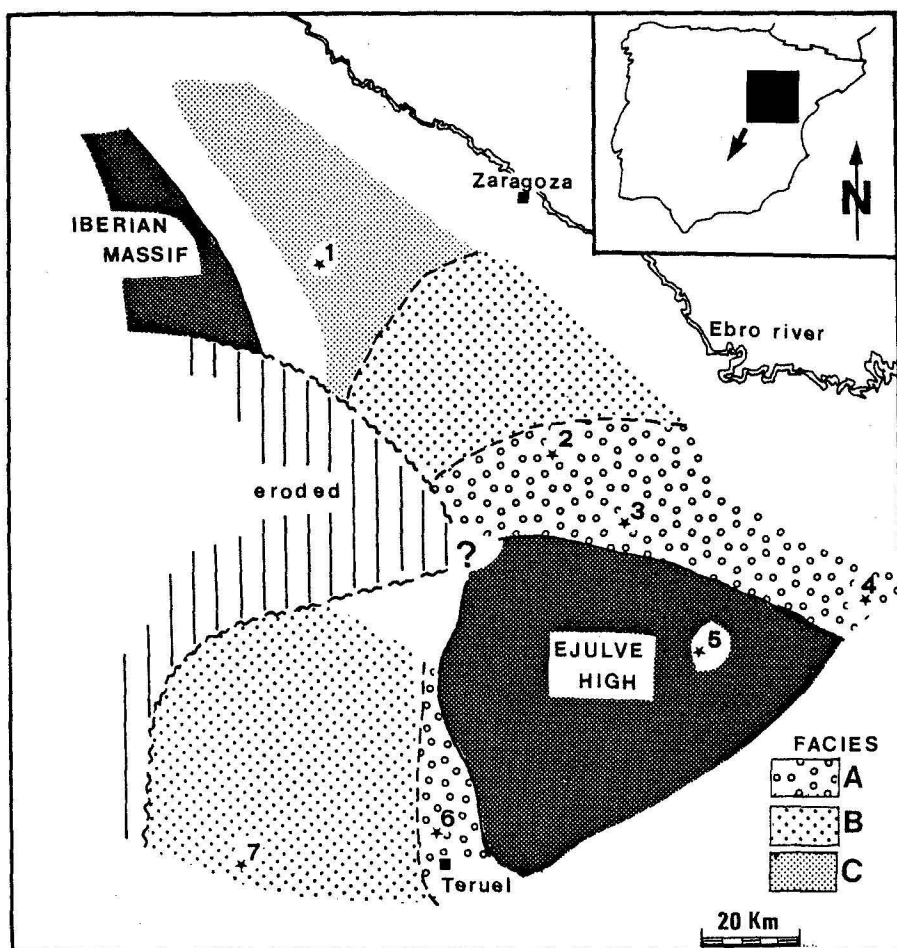


Figure 2 - Facies distribution at the Lower to lowermost Middle Oxfordian in the central part of the Iberian Basin. A, fossiliferous wackestone, bearing poorly sorted iron ooids and pisoids ; B, fossiliferous wackestone to packstone bearing well-sorted iron ooids ; C, fossiliferous wackestone. Numbers 1-7 correspond to the sections referred to in figure 3. *Distribution des faciès à l'Oxfordien inférieur - partie inférieure de l'Oxfordien moyen dans la partie centrale de la Chaîne Ibérique. A, wackestone à fossiles, avec des oïdes et pissoïdes mal classés ; B, wackestone - packstone à fossiles avec oïdes bien classés ; C, wackestone fossilifère. Les numéros 1-7 correspondent aux coupes représentées sur la figure 3.*

ve High was progressively covered by marine sediments, deposited during the major marine transgressive phases of Middle Oxfordian and Lower Kimmeridgian.

The facies distribution at the onset of the Oxfordian in the central part of the Iberian Range is shown in Figure 2. Callovian and Lower Oxfordian sediments are not recorded in the area of the Ejulve High. The Middle - Upper Jurassic unconformity displays here the maximal range, from Middle Bathonian to Middle Oxfordian (Bulard 1972 ; Aurell 1990). Calcareous oolitic grainstone from the Middle Bathonian are overlain by an unconformity, which in some localities corresponds to a subaerial karstic surface (Aurell 1990, 1991). The oolitic ironstone level appears well developed, from several centimeters to one meter of thickness, on the margins of the Ejulve High (Fig. 3).

FACIES DISTRIBUTION

From the sedimentological point of view, two components may be distinguished in the oolitic

ironstone level : the carbonate-composed grains (micrite and skeletal fragments as ammonites, belemnites, brachiopods, bivalves, gastropods, foraminifera, echinoids, crinoids and sponges in some cases) and the iron-composed grains (ooids and pisoids).

Iron-ooids, from 1 to 2 mm in diameter, are composed of concentric layers from 10 to 35 μ m thick. In addition, iron pisoids from 1 to 2 cm of diameter and irregular coatings are locally observed. The cores of the iron ooids and pisoids are fragments of broken ooids or quartz grains. Their mineralogical composition is goethite with traces of both kaolinite and carbonate hydroxy-apatite. Towards the surroundings of the Ejulve High, near the locality of Raffles, the oolitic ironstone level grades into a several centimeter thick massif carbonate-ferruginous crust, containing also iron ooids and pisoids. The mineralogical analysis of this crust shows a high content in kaolinite and goethite.

Two distinctive facies bearing iron ooids are differentiated. Their distribution is shown in Figure

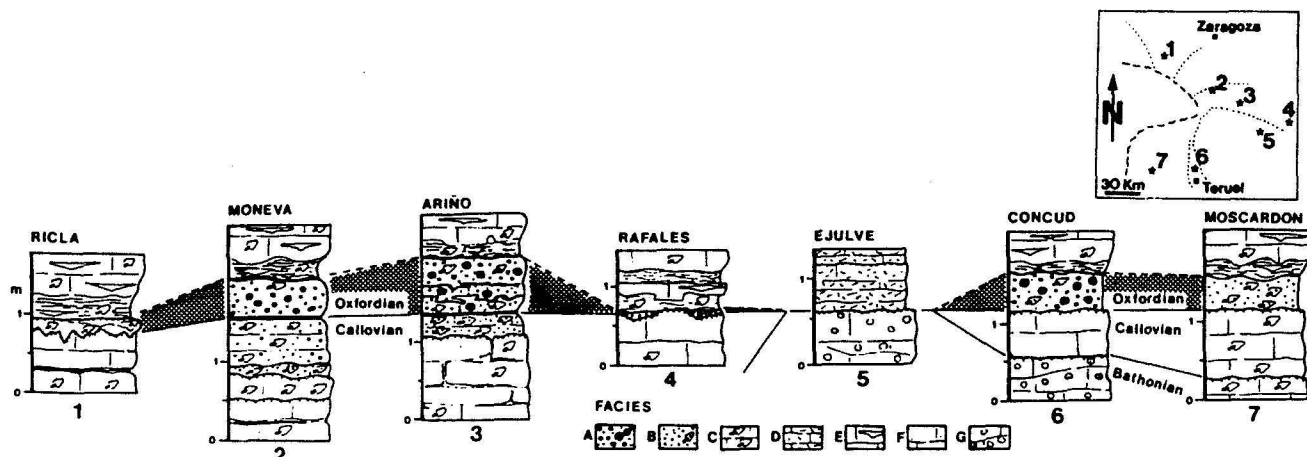


Figure 3 - Selected sections showing the main lithological features at the Middle-Upper Jurassic boundary. Location of the sections as indicated on figure 2. Facies A, wackestone, bearing poorly-sorted iron ooids and pisoids ; B, wackestone to packstone, bearing well-sorted iron ooids ; C, ammonite wackestone ; D, bioclastic packstone ; E, sponge and ammonite wackestone ; F, silty mudstone to wackestone ; G, calcareous oolitic grainstone. *Coupes sélectionnées montrant les variations lithologiques à la limite Jurassique moyen-supérieur. La localisation des coupes est indiquée sur la figure 2. Faciès A, wackestone à oïdes et pisoides mal classés ; B, wackestone à packstone à oïdes ferrugineux bien classés ; C, wackestone à ammonites ; D, packstone bioclastique ; E, wackestone à spongiaires et ammonites ; F, mudstone à wackestone silteux ; G, grainstone à oolites calcaires.*

2. The facies B spreads across distant areas of the Ejulve High and consists of fossiliferous wackestones to packstones bearing well-sorted iron ooids from 1 to 2 mm in diameter (Moscardon in fig. 3, Pl. 1, fig. 1). The facies A, which forms a narrow band around the Ejulve High (Moneva, Ariño, Rafales, Concud), shows basically the same texture but iron grains are poorly sorted, containing iron pisoids up to 1-2 cm of

diameter (Pl. 1, fig. 2). The fossil contents is generally higher in facies B than in facies A, although the groups remarked above are generally present in both facies.

The progressive increase in the sorting of the iron ooids from the elevated areas of the Ejulve High towards the center of the basin, suggests reworking and transport of sedimentary iron

PLATE 1

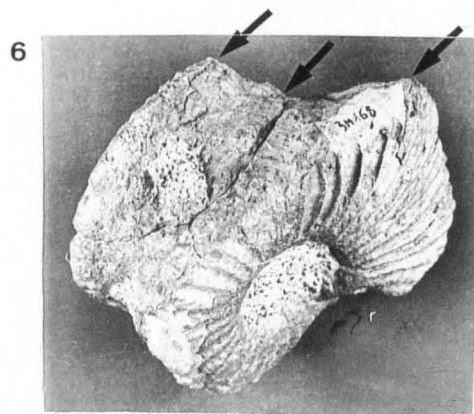
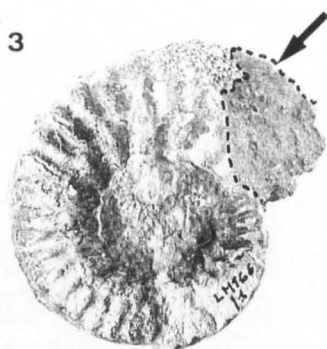
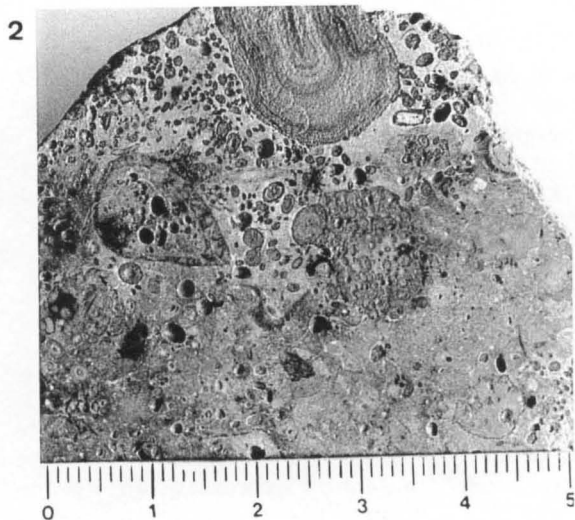
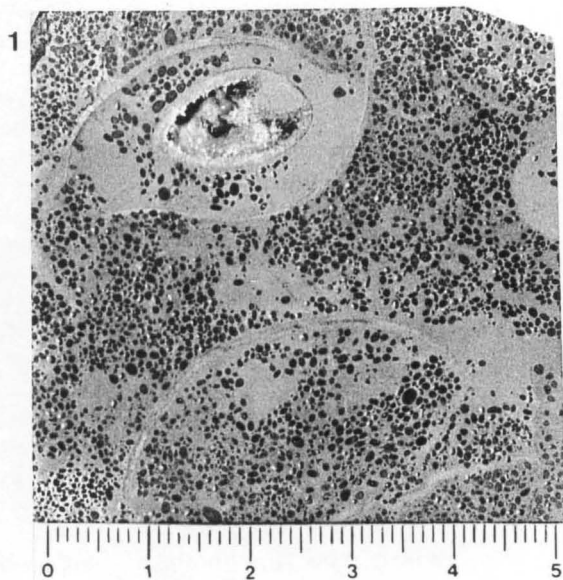
Fig. 1 - Polished section of the oolitic ironstone level at Moscardon (Sierra de Albarracín, Teruel) : fossiliferous wackestone bearing well-sorted iron ooids (scale in cm). *Section polie dans le niveau d'oolites ferrugineuses à Moscardon (Sierra de Albarracín, Teruel) : wackestone à fossiles avec oïdes ferrugineux bien classés.*

Fig. 2 - Polished section of the iron-oolite bed at Concud (Teruel) : fossiliferous wackestone bearing poorly-sorted iron ooids and pisoids (scale in cm). *Section polie dans le niveau d'oolithes ferrugineuses à Concud (Teruel) : wackestone fossilifère avec oïdes et pisoides ferrugineux mal classés.*

Fig. 3 - Reelaborated inner mould of ammonite (*Hecticoceratinae*) from the lower Callovian showing a well-developed ellipsoidal abrasion facet on the final part of last preserved whorl. Oolitic ironstone level, Moscardon (x 1). *Moule interne d'ammonite réélaboré (Hecticoceratinae) du Callovien inférieur, avec une facette ellipsoïdale d'usure bien développée sur le dernier tiers du tour de spire. Niveau d'oolites ferrugineuses, Moscardon, Sierra de Albarracín, Teruel (x 1).*

Fig. 4 - Reelaborated inner mould of ammonite (*Choffatia* sp.) from the lower Callovian, showing a well-developed ellipsoidal abrasion facet on the final part of the last preserved whorl. Oolitic ironstone level, Moscardon (x 1). Same level and outcrop as in fig. 3. *Moule interne d'ammonite réélaboré (Choffatia sp.) du Callovien inférieur montrant une facette ellipsoïdale d'usure bien développée dans le dernier tiers de tour de spire. Moscardon (x1). Même niveau et affleurement que pour la fig. 3.*

Fig. 5, 6 - Two reelaborated inner moulds of *Macrocephalites* sp. (lower Callovian), from the oolitic ironstone level of Moscardon (Sierra de Albarracín, Teruel) displaying a wide, well-developed, somewhat encrusted annular abrasion furrow. Note specially, the ornamentation preserved on both sides of the ammonite contrasting with the sharp borders of the furrow, which exclude a long transport after the exhumation of the moulds. *Deux moules internes de Macrocephalites sp. (Callovien inférieur), réélaborés, avec creusement d'un sillon annulaire d'usure, large et profond, partiellement encroûté. Remarquer spécialement l'ornementation bien conservée sur les deux flancs contrastant avec les bords anguleux du sillon, qui exclut un long transport après l'exhumation des moules internes.*



grains of facies B. It is worth noting that, despite the relative abundance of these grains in the matrix, skeletal fragments and bioclasts are rarely found in the cores of the ooids. This evidence gives further support to the idea of transport of the iron-ooids from the source area (Ejolve High) to the areas respectively of facies A and B.

THE ORIGIN OF IRON-OIDS

The origin and mode of deposition of the oolitic ironstones has been discussed for more than a century in separated areas and through the geological times (see revisions in Kimberley 1978 ; Guerrak 1988). No general agreement on a particular model to explain the origin of the oolitic ironstone beds has been reached.

One of the main problems to interpret the origin of these oolitic facies is that there is no modern counterpart to compare with. Iron ooids and pisoids very similar in composition and shape to those described here have been reported from lateritic sections in recent environments (Nahon *et al.* 1980 ; Bardossy 1982). A lateritic origin for Jurassic iron ooids and their subsequent resedimentation in the marine basin was proposed by Siehl and Thein (1978) in the "Minette facies" (West Germany).

In the Iberian Basin we propose a similar model on the origin of the oolitic ironstone level. The iron ooids and pisoids are interpreted as produced by lateritic weathering in the emerged areas, as the Ejolve High. The presence of kaolinite in the iron-ooids suggests meteorization processes. The main source-components for the iron supplies are supposed to have been provided by the weathering processes of the western emerged areas and of the volcanic rocks located southwards from the Ejolve High. In the Jurassic of the Iberian Basin, however, iron oolitic grains are mixed with marine fossils. Several sporadic flooding episodes which could partly reach the emerged areas, would have favored the transport and distribution of the iron oolitic grains across the near marine areas.

DISTRIBUTION OF AMMONITE ASSEMBLAGES

Several ammonite assemblages can be recognized within the oolitic ironstone level. The taxonomic composition and the distribution of the ammonite assemblages in the oolitic ironstone level differs from place to place (Meléndez & Brochwicz-Lewinski 1983 ; Lardiés 1990 ; Meléndez 1989 ; Fontana & Meléndez 1990).

From a biostratigraphical point of view, two or three separate stratigraphic intervals can be distinguished within the oolitic ironstone level as in the sections of Moneva, Ariño and Rafales (Fig. 3). The lower one contains ammonites of lower and/or middle Callovian, and overlies a discontinuity surface above the *Macrocephalus* Zone, involving a stratigraphic gap. The upper stratigraphic interval may contain several mixed assemblages with common ammonites characteristic of the Middle Oxfordian. In some localities, an intermediate stratigraphic interval may be distinguished containing mixed assemblages dominated by Callovian ammonites, associated with scarce lower and Middle Oxfordian ammonites.

On the basis of the taphonomical features displayed by the ammonites, two separate assemblages have been identified, within the upper oolitic bed, in most of the studied localities (Meléndez *et al.* 1983 ; Meléndez & Brochwicz-Lewinski 1983 ; Meléndez 1989). A first ammonite assemblage formed mainly by *Prososphinctes*, *Peltoceratoides*, *Neocampylites*, is considered as typical of the Claromontanus Subzone (= lower part of Cordatum Zone). A second Oxfordian ammonite assemblage is formed by *Per.(Otosphinctes)* of the *paturattensis-montfalconensis* DE LORIO groups, which characterize the lower part of the Vertebrale Subzone, Plicatilis Zone (=Paturattensis Horizon). In some localities, such as Ariño and Moneva, a third ammonite assemblage is recorded at the upper part of the oolitic ironstone level. This third assemblage is formed by ammonites characteristic of the lower part of the Transversarium Zone (Parandieri and/or Luciaeformis Subzones), such as *Per.(Perisphinctes)* cf. *parandieri* DE LORIO ; *Per. (Dichotomosphinctes) luciaeformis* ENAY ; *Per. (Otosphinctes) nectobrigensis* MELENDEZ.

In other areas, the oolitic ironstone level appears represented by a single oolitic bed, as in Moscardon (Sierra de Albarracín). In these cases, an admixture of reworked ammonites from Lower Callovian to Lower-Middle Oxfordian is recorded within a decimetrically thick level. This level overlies a discontinuity surface above *Macrocephalus* Zone (Herveyi Zone according to the recent proposal by Callomon *et al.* 1988). In the northwestern part of the Iberian Range (Ricla), this transitional level is represented as well by one single bed. In the section of Ricla a decimetrically thick micritic bed without iron oolites, contains a mixed assemblage from the Lamberti and lower Cordatum Zones. Its lower boundary is a highly uneven surface digging deeply (up to 20 cm) in the underlying Upper Callovian beds and tracing a se-

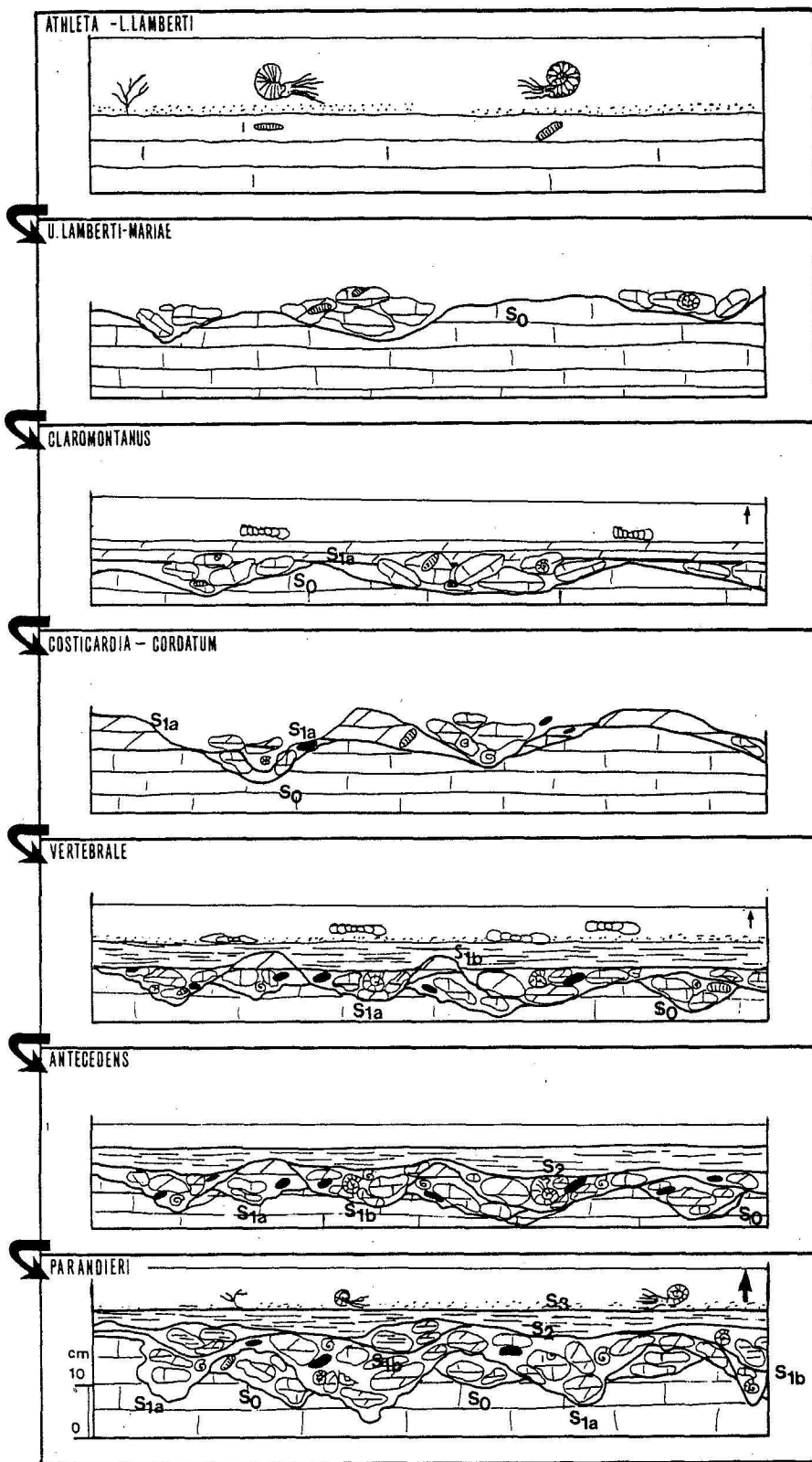


Figure 4 - Sketch of the inferred succession of events between the Upper Callovian and Middle Oxfordian at the locality of Ricla, showing the main episodes of subaerial erosion and the minor flooding events during this interval. (From Fontana, 1990). A regular process of carbonate sedimentation took place up to the lower part of Athleta Zone in an open marine environment. The most important events of subaerial erosion and reworking of fossils took place during the Lamberti and Mariae Chrons. From Claromontanus Subzone to Parandieri Subzone the sedimentation was very discontinuous. The main erosive phases in this interval, which led to the development of the irregular erosive surfaces (S₁ to S₃) took place respectively during the Costicardia and Cordatum Subchrons and the upper Vertebrale and Antecedens Subchrons. Minor flooding episodes are recorded at the lower Cordatum Zone (Claromontanus Subzone) and at the lower Vertebrale Subzone (Paturattensis Horizon). Succession d'événements entre le Callovien supérieur et l'Oxfordien moyen à Ricla, avec les phases d'érosion probablement subaérienne, et les petits intervalles d'inondation de la plate-forme. La sédimentation carbonatée reste constante dans un environnement marin ouvert jusqu'au début de la zone à Athleta. La période d'érosion la plus importante correspond à l'intervalle des chrons Lamberti et Mariae, avec le remaniement des fossiles. De la sous-zone à Claromontanus à la sous-zone à Parandieri, la sédimentation était très discontinue. Les phases érosives responsables de la formation des surfaces S₁ à S₃ ont lieu respectivement pendant les sous-chrons Costicardia, Cordatum, Vertebrale (p.p.) et Antecedens. Des inondations mineures se produisent au début de la zone à Cordatum (sous-zone à Claromontanus) et de celle à Vertebrale (horizon à Paturattensis).

ries of irregular cavities or pockets (Meléndez *et al.* 1983), which reflect a complex succession of sedimentary and erosion events (Fig. 4).

In the areas surrounding the Ejulve High the sediments from Lower Callovian to Middle Oxfordian are very reduced to totally absent. The oolitic ironstone level is represented by a very thin bed, from 1 to 5 cm containing iron ooids and pisoids, as it is the case in the Rafales section. In the central part of the Ejulve High (Ejulve section) the oolitic ironstone level is absent. In this area, thick calcareous oolitic grainstone banks, of presumably Bathonian age, are truncated by an erosional surface. This surface is overlain by the Middle Oxfordian (Transversarium Zone) bioclastic packstone facies.

TAPHONOMIC ANALYSIS

The fossil contents of the oolitic ironstone level is relatively abundant throughout the studied area. It is mainly formed by ammonites, belemnites, brachiopods and bivalves. Gastropods and foraminifera may be common, as well as sponge spicules in some cases. In certain localities, iron oolites are also found at the Lower part of the overlying Middle Oxfordian sponge limestone unit, the so-called Yatova Formation. Siliceous sponges, preserved as calcitic pseudomorphs, and crinoids are the main bioclastic component of this lithostratigraphic unit.

The taphonomic analysis of the fossil assemblages found in the oolitic ironstone level has come to be indispensable in order to resolve several important questions, such as (1) the origin of the mixed assemblages, (2) the age of the bed, and (3) the sedimentary conditions of this bed or its depositional setting.

THE ORIGIN OF MIXED ASSEMBLAGES

The ammonite assemblages of this Callovian-Oxfordian boundary bed can be described as typical condensed assemblages, formed by an admixture of Callovian, Lower Oxfordian and, occasionally, Middle Oxfordian ammonites. The fossilization process can be best understood on the basis of a detailed analysis of (a) the taphonomic evidence, and (b) the origin of the ammonite assemblages.

Taphonomic Evidence

The detailed analysis of the condensed assemblages from the oolitic ironstone level shows that the mixing of inner moulds and shells of ammonites was a common process during the Lower Callo-

vian-Middle Oxfordian interval. For this reason it is necessary, before any biostratigraphical determination of the beds, to distinguish between reworked or reelaborated fossils and resedimented fossils.

The term taphonomic reworking or *taphonomic reelaboration* (proposed by Fernández-López 1984, 1991, p. 41) means the exhumation and displacement of remains and/or traces of palaeobiological entities. Before their final burial, during the reelaboration process, some inner moulds of the oolitic ironstone level developed particular taphonomic features such as: phosphatic cements, coating by iron-crusts, as well as disarticulation or fracture surfaces, abrasion facets, and traces of bioerosion or encrusting organisms. *Taphonomic resedimentation* means the displacement on the substrate of remains and/or traces before their burial. Several remarks can be pointed out from this taphonomical process:

- reelaborated and resedimented fossils may be found together in the same bed, but they are diachronous. In the case of ammonites, reelaborated fossils are older than those resedimented, and the age of the bed containing a condensed assemblage is that of the resedimented fossils;
- reelaborated ammonites, or reworked ammonites derived from older sediment, should not be used to define or recognize biostratigraphic units (cf. N.A.C.S.N. 1983, p. 862);
- the process of taphonomic reelaboration involves the remobilization of a sediment and the exhumation of fossils. This entails an increase of the turbulence, so in a sedimentary sequence an increase in the frequency of reworked fossils can be correlated with an increase of the turbulence in the sedimentary environment;
- although there is not an obvious relationship between taphonomic reelaboration and bathymetric conditions, some particular features observed on the reelaborated ammonites within the oolitic ironstone level are best explained as developed under very shallow environmental conditions, most probably in intertidal environments (Fernández-López 1985a, 1985b). This is the case of the so-called *ellipsoidal abrasion facets* developed preferentially in the final part of the last preserved whorl and of the *annular abrasion furrows* carved on the external region of some inner moulds of ammonites still displaying the ornamentation preserved on both sides (Plate 1, figs. 3-6).

These abrasion features would result from the carving effect of unidirectional currents during the process of reelaboration of inner moulds. The response of these inner moulds to the currents

would determine them to orientate with the body chamber (or the preserved outer whorl) facing the current, this final part of the last whorl being differentially eroded. The result will be an ellipsoidal abrasion facet or an annular abrasion furrow, still preserving the ornamentation on both flanks, if the water layer is not thick enough to erode the upper side of the ammonite (Pl. 1, fig. 5-6).

The origin of ammonite assemblages

In the Iberian Range, inner moulds of ammonites showing annular abrasion furrows and/or ellipsoidal abrasion facets on the final part of last preserved whorl are common and have been repeatedly recorded within the oolitic ironstone level of all the studied localities. It is worth noting that the ammonites showing such traces are, in most cases, Callovian in age, belonging to subfamilies Macrocephalitinae, Hecticoceratinae, Pseudoperisphinctinae, Grossouvriinae, Peltoceratinae. Only in the northwestern part (Ricla) ammonites from the Upper Callovian and Lower Oxfordian are found showing these taphonomic features. It is also interesting to note, from the biogeographical point of view, that the whole content of the ammonite assemblages may be regarded as typically submediterranean.

The presumable succession of events which determined the origin of the condensed assemblage of the Dogger-Malm boundary level in the Iberian Basin has been reconstructed in detail in Ricla (from Fontana 1990, see Fig. 4). It is interpreted that, from Early Callovian to Middle Oxfordian a process of shallowing and eventually emersion took place on this carbonate platform in different moments, according to the different areas. This resulted in several successive episodes of remobilization of the sediment and reelaboration of fossils, punctuated by short intervals of flooding of the platform. These brief intervals of flooding took place most probably during the Claromontanus and Paturattensis (early Vertebralis) Subchrons.

The taphonomic evidence indicates that the presence of ammonites in this level results from post-mortem drifting of shells (see Meléndez *et al.* 1990). The arrival of these ammonite shells is much better understood as drifted shells, since the fossil assemblages correspond to taphonomic associations of the type 3 (AT-3 according to the classification proposed by Fernández-López 1985c, p. 754, Fernández-López & Gómez 1990, p. 49). These assemblages show consistent evidence of allochthony, such as :

- the size-frequency distribution of the assemblages appear asymmetric and sometimes polymodal, showing negative bias ;
- the ammonite assemblages are dominated by adult specimens, the young individuals being absent or exceptional ;
- ammonite assemblages are never monotypic at a specific level, i.e. assemblages for each genera are always composed by specimens of several species ;
- the ratio of species number to the number of specimens is significantly high, sometimes close to 1.

THE AGE OF THE BED

The ammonite content of the oolitic ironstone level has allowed the different authors to propose accurate datings for this level. The Callovian ammonites of the oolitic ironstone level were described by Marin & Toulouse 1972 ; Sequeiros 1982a, 1982b, 1984 ; Sequeiros *et al.* 1984 ; Lardiés 1989. The Lower Oxfordian ammonite assemblages have been described by Meléndez *et al.* 1983 ; Meléndez & Brochwicz-Lewinski 1983 ; Meléndez 1989.

A remarkable feature, which has traditionally made difficult the accurate dating of this level, is the presence in the same bed of condensed ammonite assemblages, characterizing the lower to Upper Callovian, the Lower Oxfordian and, sometimes, even the Middle Oxfordian. As stated above, the oolitic ironstone level, as a highly complex sedimentary interval, may be formed by one or two oolitic limestone beds separated by irregular, ferruginous surfaces. Each oolitic bed may even be composed of several layers, or sets of layers, only few centimeters thick, which may contain different ammonite assemblages and, in some cases, a condensed assemblage integrated by ammonites characteristic of several biostratigraphic units.

The erosional surface underlying the oolitic ironstone level appears markedly diachronous from the Northwest (Ricla area) to the Southeast (Calanda - Rafales) and the central Iberian Range (Sierra de Albarracín). As a general rule, this boundary is associated to a widespread biostratigraphic gap, ranging from Lower or Middle Callovian to Lower Oxfordian, so the Callovian-Oxfordian boundary corresponds to the lower boundary of this level. Callovian ammonites, may be found as reelaborated moulds within this bed, but the age of the bed is, in fact, lower or even Middle Oxfordian (Fig. 5). However, in the region of Sierra de Arcos (Moneva - Ariño), at the borders of the Ejulve High, two iron- oolitic beds are

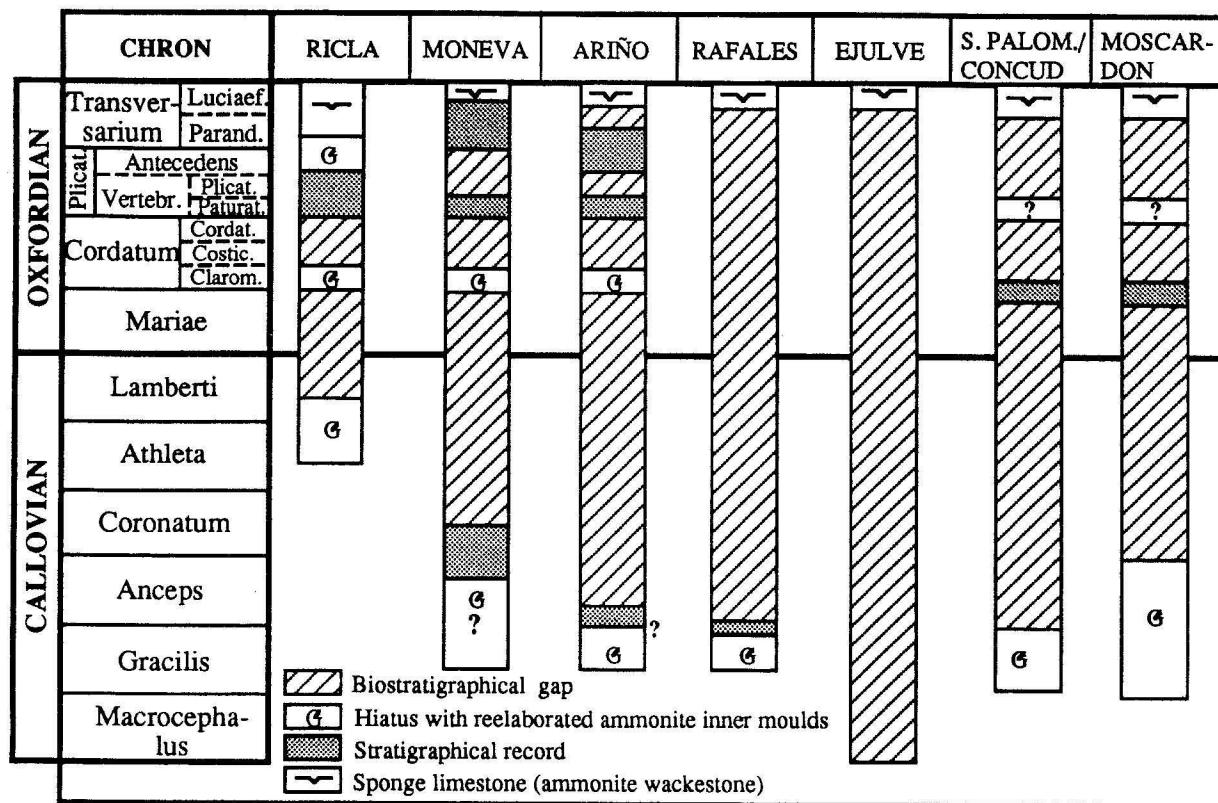


Figure 5 - Correlation chart to show the inferred age of the oolitic ironstone level (or its lateral equivalent) and the biostratigraphic range of the gaps involved in the different localities of the studied area. The maximum biostratigraphical range of the gap corresponds to the Rafales (Calanda) - Ejulve area, on the so-called Ejulve High. In the area of the Sierra de Arcos, in Moneva - Ariño, a first iron-oolitic bed, early to middle Callovian in age, is recorded. The age of the upper iron-oolitic bed (Oxfordian) may change from early to middle Oxfordian in the different localities. *Tableau de corrélation montrant l'âge du niveau d'oolites ferrugineuses (ou ses équivalents latéraux) dans les différentes localités étudiées. L'amplitude biostratigraphique maximale de la lacune correspond à la région de Rafales (Calanda) - Ejulve, dans la région du haut-fond d'Ejulve. Dans la Sierra de Arcos (Moneva - Ariño), on trouve un premier niveau, d'âge variant du Callovien inférieur au Callovien moyen. L'âge du niveau oolitique supérieur (Oxfordien) peut varier de l'Oxfordien inférieur à la partie inférieure de l'Oxfordien moyen dans les différentes localités.*

distinguished. The lower one contains only Callovian ammonites, and its presumable age is of Early to Middle Callovian. The Callovian-Oxfordian boundary lies, in these cases, between both oolitic beds.

The age of the upper iron-oolitic bed may sometimes be difficult to assess, due to practical problems in analyzing the taphonomic state of preservation of ammonites. In the central part of the Iberian Range (Sierra Palomera; Sierra de Albaracín), ammonites from the lower Oxfordian, *Claramontanus* Subzone such as *Prososphinctes claramontanus* (BUKOWSKI) and *Peltoceratoides* sp. are found as resedimented ammonites within this bed, so the age of the bed is early Cordatum Zone. In the northern part, between Ricla and the Calanda area, these Lower Oxfordian ammonites are usually recorded as reelaborated fossils,

whilst those from lower Vertebrata Subzone (*Per. paturattensis* assemblage), and sometimes up to lower Transversarium Zone, are recorded as resedimented fossils. So, it is possible to distinguish here several successive layers within this bed, from Vertebrata to Luciaeformis Subzones (see Fig. 5).

According to the exposed data, three main biostratigraphic gaps can be recognized during the Callovian-Oxfordian interval in the central Iberian Range. (1) At the Callovian-Oxfordian boundary, at least, from Lamberti Zone to the bottom of the Cordatum Zone. (2) At the Lower-Middle Oxfordian boundary, spanning the Costicardia and Cordatum Subzones. (3) At the Middle Oxfordian, ranging from upper Vertebrata Subzone to middle Transversarium Zone (Luciaeformis Subzone).

INTERPRETATION OF THE DEPOSITIONAL SETTING

The sedimentological features of the facies of the oolitic ironstone level and their distribution throughout the studied area show the homogeneity of the depositional setting, into which no major palaeogeographic breaks or depositional slopes are found. This suggests sedimentation on an extensive and homogeneous low-angle ramp setting (Aurell & Meléndez 1993). The most elevated areas of this ramp were located farther southeast, at the borders of the Ejulve High. This shoal is interpreted as a topographic high that remained emerged during this episode, showing no stratigraphic record of these minor flooding events which took place during the early Cordatum and Plicatilis Chrons respectively. The flooding events would have favored the arrival of ammonites, as drifted shells, to this area and the distribution of iron oolites throughout the platform. In the same way, during those episodes corresponding to the widespread hiatuses most of the ramp was exposed or covered only by a very thin layer of water.

EUSTATIC IMPLICATIONS

The discussion on the bathymetric conditions of the platform at the Middle - Upper Jurassic boundary has some relevant implications for basin analysis and specially in the intent to depict a possible eustatic curve. An eustatic control upon the genesis of the Callovian - Oxfordian unconformity, separating third order cycles, is suggested by the coincidence of the stratigraphic position of the condensed sections in geographically separated basins (Haq *et al.* 1987 ; Hallam 1988 ; Legarreta 1991 ; Aurell 1991 ; Rioult *et al.* 1991). The Middle - Upper Jurassic oolitic ironstone level was interpreted as a condensed section in the Paris basin by Vail *et al.* (1987). In this basin the Callovian - Oxfordian boundary level is considered, in the Exxon curve (Haq *et al.* 1987), to represent the marine condensed section of the third order eustatic cycle ZA.3.2. By correlation with the Exxon curve, Legarreta (1991) also proposes that the stratigraphic hiatus recorded at the Callovian-Oxfordian boundary (from Athleta to lower Cordatum Zone) in the Neuquen Basin (West-central Argentina) corresponds to a condensed section.

The oolitic ironstone level in the Iberian Basin also shows typical features of stratigraphic condensation, but it is interpreted as deposited under very shallow marine environmental conditions. From the point of view of the Sequence

Stratigraphy approach, this oolitic ironstone level would not represent a single phenomena, but a complex history. At least two eustatic cycles which reached the maximum flooding of the ramp at the early Cordatum and Plicatilis Chrons are detected. It should be noted that, as pointed before in previous works (Aurell 1990) the oolitic ironstone level would represent an interval in which the relative depth of the Oxfordian ramp reached a minimum. This ramp was flooded up during the Middle Oxfordian (Transversarium Chron) and extensively colonized by benthic and nectonic marine groups (sponges, ammonites, crinoids, brachiopods, ahermatipic corals, forams, and other).

CONCLUSIONS

An integrated analysis of the oolitic ironstone level of the Callovian-Oxfordian boundary in the central Iberian Basin, including both the facies analysis, the distribution of ammonite assemblages, and the taphonomic and biostratigraphical data, has yielded a number of data which leads to the interpretation of the oolitic ironstone level as formed under very shallow marine environmental conditions. Iron ooids and pisoids were generated by weathering processes on the emerged areas of the sedimentary highs. The resedimentation of the iron-ooids from these areas to the near marine areas of the platform took place mainly during several ephemeral flooding events, which reached also the marginal areas of the sedimentary highs. The arrival of the ammonites to these shallow marine environments, mainly from the submediterranean province, took place during these flooding intervals mainly as drifted shells.

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REFERENCES

- AURELL M. 1990 - El Jurásico superior en la Cordillera Ibérica Central (provincias de Zaragoza y Teruel). Análisis de cuenca. *Tesis Doctoral, Dpto. Geología, Serv. Public. Univ. de Zaragoza* : 1-389.
AURELL M. 1991 - Identification of systems tracts in low angle carbonate ramps : examples from the Up-

- per Jurassic of Iberian Chain (Spain). *Sediment. Geol.*, **73** : 101-115.
- AURELL M. & MELENDEZ A. 1993 - Sedimentary evolution and sequence stratigraphy of the Upper Jurassic in the central Iberian Chain, northeast Spain. In POSAMENTIER H.W., SUMMERHAYES C.P., HAQ B.U. & ALLEN G.P. (eds.) : Sequence Stratigraphy and Facies Associations. *Int. Assoc. Sediment., Spec. Publ.*, **18** : 343-368.
- BARDOSY G. 1982 - Karst bauxites. Bauxite deposits in carbonate rocks. Elsevier Scient. Pub. comp., Amsterdam : 441 p.
- BENKE K. 1981 - Die Dogger-Malm Wende in den NW Keltiberischen Ketten (Spanien) und angrenzenden Gebieten. *Sedimentologie, Stratigraphie und Paläogeographie. Facies*, **4** : 95-164.
- BULARD P.F. 1972 - Le Jurassique moyen et supérieur de la Chaîne Ibérique sur la bordure du bassin de l'Ebre (Espagne). *Thèse. Fac. Sciences, Univ. Nice* : 1-702.
- CALLOMON J.H., DIETL G. & PAGE K.N. 1988 - On the ammonite faunal horizons and standard zonations of the Lower Callovian stage in Europe. In ROCHA R.B. & SOARES A.F. (eds.) : 2nd International Symposium on Jurassic Stratigraphy, Centro de Estratigrafia e Paleobiologia da Universidade Nova de Lisboa (INIC) : 261-274.
- CANEROT J. 1985 - Le cycle alpin des Ibérides. *Strata*, **2** : 15-31.
- FERNANDEZ-LOPEZ S. 1984 - Nuevas perspectivas en tafonomía evolutiva : Tafosistemas y asociaciones conservadas. *Estudios Geológicos*, **40** : 215-224.
- FERNANDEZ-LOPEZ S. 1985a - Criterios elementales de reelaboración tafonómica en ammonites de la Cordillera Ibérica. *Acta Geológica Hispánica*, **19** : 105-116.
- FERNANDEZ-LOPEZ S. 1985b - Séquences sédimentaires et séquences taphonomiques. *Strata*, **2** : 116-121.
- FERNANDEZ-LOPEZ S. 1985c - El Bajociense en la Cordillera Ibérica. *Tesis Doctoral, Dpto. Paleontología, Univ. Complutense, Madrid* : 1-850.
- FERNANDEZ-LOPEZ S. 1991 - Taphonomic concepts for a theoretical Biochronology. *Revista Española de Paleontología*, **6** : 37-49.
- FERNANDEZ-LOPEZ S. & GOMEZ J.J. 1990 - Evolution tectono-sédimentaire et genèse des associations d'ammonites dans le secteur central du bassin Ibérique (Espagne) pendant l'Aalénien. *Cahiers Univ. Catho. Lyon, ser. Sci.*, **4** : 39-52.
- FERNANDEZ-LOPEZ S., MELENDEZ G. & SUAREZ VEGA L.C. 1978 - El Dogger y Malm en Moscardón (Teruel). *Grupo Español de Mesozoico, Guía exc. Jurásico Cordillera Ibérica*, **6** : 1-20.
- FONTANA B. 1990 - El Oxfordiense Medio, Biozona Transversarium (Jurásico Superior) en el borde sur de la Cuenca del Ebro (Cordillera Ibérica). Estudio Paleontológico del Género *Larcheria* (Perisphinctidae). *Tesis Licenciatura, Univ. de Zaragoza* : 1-123.
- FONTANA B. & MELENDEZ G. 1990 - Caracterización bioestratigráfica de la Biozona Transversarium (Oxfordiense Medio) en el sector oriental de la Cordillera Ibérica. *Geogaceta*, **8** : 76-78.
- GOMEZ J.J. 1979 - El Jurásico superior en facies carbonatadas del sector levantino de la Cordillera Ibérica. *Tesis Doctoral, Univ. Complutense de Madrid*.
- Seminarios de Estratigrafía (serie monografías)*, **4** : 1-683.
- GUERRAK S. 1988 - Paleozoic marine sedimentation and associated oolitic iron-rich deposits, Tassalis N'Ajjer and Illizi Basin, Saharan platform, Algeria. *Eclogae Geol. Helv.*, **81** : 457-485.
- GYGI R.A. 1981 - Oolitic iron formations : marine or not marine? *Eclogae Geol. Helv.*, **74** : 233-254.
- GYGI R.A. 1986 - Eustatic sea level changes of the Oxfordian (late Jurassic) and their effect documented in sediments and fossil assemblages of an epicontinental sea. *Eclogae Geol. Helv.*, **79** : 455-491.
- HALLAM A. 1988 - A reevaluation of Jurassic Eustasy in the light of new data and the revised Exxon curve. In WILGUS C.K., HASTINGS B.S., KENDALL C.G.S.C., POSAMENTIER H.W., ROSS C.A. & VAN WAGONER J.C. (eds.) : Sea Level Changes : An Integrated Approach, *Soc. Econom. Paleontol. Mineral., Spec. Public.*, **42** : 261-274.
- HAQ B.H., HARDENBOL J. & VAIL P.R. 1987 - Chronology of fluctuating sea levels since the Triassic. *Science*, **235** : 1156-1167.
- KIMBERLEY M.M. 1978 - Paleoenvironmental classification of Iron Formations. *Economic Geology*, **73** : 215-229.
- LARDIES M.D. 1989 - Estudio bioestratigráfico y paleontológico del Calloviense (Jurásico Medio) en el sector central de la Cordillera Ibérica. *Tesis Licenciatura, Lab. Paleontología, Univ. Zaragoza* : 1-209.
- LARDIES M.D. 1990 - Observaciones bioestratigráficas y sedimentológicas sobre el Calloviense en la provincia de Zaragoza. *Cuadernos de Geología Ibérica*, **14** : 157-172.
- LARDIES M.D., MELENDEZ G. & SEQUEIROS L. 1988 - Nuevos datos sobre el Calloviense del sector central de la Rama Aragonesa (Cordillera Ibérica). Bioestratigrafía y facies. *II Congreso Geológico de España, Granada V.I.* : 293-296.
- LEGARRETA L. 1991 - Evolution of a Callovian-Oxfordian carbonate margin in the Neuquen Basin of west-central Argentina: facies, architecture, depositional sequences and global sea-level changes. *Sedimentary Geol.*, **70** : 209-240.
- MARIN Ph. & TOULOUSE D. 1972 - Le Jurassique moyen et supérieur du Nord de la prov. de Teruel (Espagne) : un exemple du passage Dogger-Malm dans la région d'Ariño-Oliete. *Estudios Geológicos*, **28** : 111-118.
- MELENDEZ G. 1989 - El Oxfordiense en el sector central de la Cordillera Ibérica (Provincias de Zaragoza y Teruel). Instituto Estudios Turolenses, Zaragoza-Teruel : 418 p.
- MELENDEZ G. & BROCHWICZ-LEWINSKI W. 1983 - El Oxfordiense Inferior en el sector central de la Cordillera Ibérica (S. Zaragoza - N. Teruel). *Teruel*, **69** : 211-226.
- MELENDEZ G., SEQUEIROS, L. & BROCHWICZ-LEWINSKI W. 1983 - Lower Oxfordian in the Iberian Chain, Spain ; (1) Biostratigraphy and nature of gaps. *Bull. Acad. Pol. des Sc. (Sc. Terre)*, **30** : 157-172.
- MELENDEZ G., AURELL M., FONTANA B. & LARDIES D. 1990 - El tránsito Dogger-Malm en el sector nororiental de la Cordillera Ibérica : análisis tafonómico

- y reconstrucción paleogeográfica. *Com. Reunión de Tafonomía y Fosilización* : 221-229.
- MENSINK H. & MERTMANN D. 1984 - Regressionen-Transgressionen während des unter-Callovium in den nordwestlichen Keltiberischen Ketten, Spanien. *Z. dt. Geol. Ges.*, **135** : 37-44.
- NAHON D., CAROZZI A.V. & PARRON C. 1980 - Lateritic weathering as a mechanism for the generation of ferruginous ooids. *J. Sedim. Petrol.*, **50** : 1287-1298.
- NORTH AMERICAN COMMISSION ON STRATIGRAPHIC NOMENCLATURE 1983 - North American Stratigraphic Code. *Amer. Assoc. Petrol. Geol. Bull.*, **67** : 841-875.
- RIOULT M., DUGUE O., JAN DU CHENE R., PONSOT C., FILY G., MORON J.-M. & VAIL P.R. 1991 - Outcrop sequence stratigraphy of the Anglo-Paris Basin, Middle to Upper Jurassic (Normandy, Maine, Dorset). *Bull. Centres Rech. Explor.-Prod. Elf Aquitaine*, **15** : 101-194.
- SEQUEIROS L. 1982a - El Calloviense de Moneva (Zaragoza). Precisiones bioestratigráficas. *Bol. Real Soc. Española Hist. Nat., Geol.*, **80** : 153-162.
- SEQUEIROS L. 1982b - Precisiones bioestratigráficas del Calloviense de Belchite (Cordillera Ibérica, Zaragoza). *Bol. Real Soc. Española Hist. Nat., Geol.*, **80** : 163-170.
- SEQUEIROS L. 1984 - Facies y ammonoideos de edad Calloviense al sur de Zaragoza (Cordillera Ibérica). *Boletín Geológico y Minero*, **95** : 109-115.
- SEQUEIROS L. 1986 - Indices de semejanza faunística en Paleogeografía: Aplicación al Calloviense inferior en España. *Paleontología i Evolució*, **20** : 311-316.
- SEQUEIROS L., CARIOU E. & MELENDEZ G. 1984 - Algunos ammonoideos del Calloviense superior de Aguilón (Zaragoza, Cordillera Ibérica). *Estudios Geológicos*, **40** : 399-410.
- SEQUEIROS L. & MELENDEZ G. 1981 - Nuevos datos bioestratigráficos del Calloviense y Oxfordiense de Aguilón (Cordillera Ibérica, Zaragoza). *Cuadernos de Geología*, **10** : 167-177.
- SIEHL A. & THEIN J. 1978 - Geochemische trends in der Minette (Jura, Luxemburg-Lothringen). *Geol. Rdsch.*, **67** : 1052-1077.
- VAIL P.R., COLIN J.P., CHENE J., KUCHLY J., MEDIAVILLA F. & TRIFILIEF F. 1987 - La stratigraphie séquentielle et son application aux corrélations chronostratigraphiques dans le Jurassique du bassin de Paris. *Bull. Soc. Géol. France*, **7** : 301-321.
- VAN WAGONER J.C., POSAMENTIER H.W., MITCHUM R.M., VAIL P.R., SARG J.F., LOUTIT T.S. & HARDENBOL J. 1988 - An Overview of the fundamentals of sequence stratigraphy and key definitions. In WILGUS C.K., HASTINGS B.S., KENDALL C.G.S.C., POSAMENTIER H.W., ROSS C.A. & VAN WAGONER J.C. (eds.) : *Sea Level Changes : An Integrated Approach*, *Soc. Econom. Paleontol. Mineral., Spec. Public.*, **42** : 39-45.
- WILDE S. 1988 - Das Bathonium und Callovium der nordwest-Iberischen Ketten (Jura, Spanien). Sequenzen einer sich differenzierenden Epikontinental-Plattform. *Bochumer geol. u. geotechn. Arb.*, **31** : 1-271.

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